Senior Design Report
for
ECE 477 – Fall 2012

submitted by
Prof. David G. Meyer
December 18, 2012

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School of Electrical & Computer Engineering

Contents

Course Description

Digital Systems Senior Design Project (ECE 477) is a structured approach to the development and integration of embedded microcontroller hardware and software that provides senior-level students with significant design experience applying microcontrollers to a wide range of embedded systems (e.g., instrumentation, process control, telecommunications, intelligent devices, etc.). The primary objective is to provide practical experience developing integrated hardware and software for embedded microcontroller systems in an environment that models one which students will most likely encounter in industry.

One of the unique features of this course is that each team gets to choose their own specific project (subject to some general constraints) and define specific success criteria germane to that project. In general, this approach to senior design provides students with a sense of project ownership as well as heightened motivation to achieve functionality.

Course web site: https://engineering.purdue.edu/ece477

Course Staff

Name	*Title / Role*	*E-mail Address*
Prof. David Meyer	Faculty / Project Advisor	meyer@purdue.edu
Dr. Mark Johnson	Faculty / Project Advisor	mcjohnso@purdue.edu
George Toh	Teaching Assistant / Project Consultant	ytoh@purdue.edu
Blaine Gardner	Teaching Assistant / Project Consultant	bbgardne@purdue.edu
Charles Barnett	Lab Technical Support	barnettc@purdue.edu

Lecture Schedule / Course Calendar

ECE 477 – *Digital Systems Senior Design Project* – Fall 2012

COURSE CALENDAR

Wk	Monday	Tuesday	Wednesday	Thursday	Friday	Wk	Monday	Tuesday	Wednesday	Thursday	Friday
1	Aug 20	Aug 21 Course Introduction 10:30-11:20 MSEE 184	Aug 22 Mods 1 & 2 Digital Design 9:00-10:20 MSEE 184	Aug 23 Module 3 uC survey 10:30-11:20 MSEE 184	Aug 24 Preliminary Proposal Due	9	Oct 15	Oct 16	Oct 17 Progress Briefings 9:00-10:20 EE 063	Oct 18	**Oct 19** **Proof of Parts and PCB Submission Due**
2	Aug 27	Aug 28 Module 4 Emb Sys I/F 10:30-11:20 MSEE 184	Aug 29 Module 5 PCB Design 9:00-10:20 MSEE 184	Aug 30 Module 6 Pow Sup Des 10:30-11:20 MSEE 184	Aug 31 Final Proposal Due	10	Oct 22	Oct 23 Module 13 Patent Liab 10:30-11:20 MSEE 184	Oct 24 **TCSP** Software 9:00-10:20 MSEE 184	Oct 25 Module 13 Patent Liab 10:30-11:20 MSEE 184	Oct 26 Software Design Narrative Due
3	Sept 3 Labor Day	Sept 4 Module 6 Pow Sup Des 10:30-11:20 MSEE 184	Sept 5 **TCSP** PSSCs 9:00-10:20 MSEE 184	Sept 6 Module 7 Pkg & Cnstr 10:30-11:20 MSEE 184	Sept 7 PCB Tutorial Exercise Due	11	Oct 29 Midterm Peer Evaluation Due	Oct 30 Module 14 Rel/Safe Anal 10:30-11:20 MSEE 184	Oct 31 **TCSP** Patent Liability 9:00-10:20 MSEE 184	Nov 1 Module 14 Rel/Safe Anal 10:30-11:20 MSEE 184	Nov 2 Patent Liability Analysis Due
4	Sept 10	Sept 11 Module 8 Pass Cmp Sel 10:30-11:20 MSEE 184	Sept 12 **TCSP** Constr Anal 9:00-10:20 MSEE 184	Sept 13 Module 8 Pass Cmp Sel 10:30-11:20 MSEE 184	Sept 14 Design Constraint Analysis Due	12	Nov 5 Lab Notebook Evaluation	Nov 6 Module 15 Eth/Env Imp 10:30-11:20 MSEE 184	Nov 7 **TCSP** Reli & Safety 9:00-10:20 MSEE 184	Nov 8 Module 15 Eth/Env Imp 10:30-11:20 MSEE 184	Nov 9 Reliability and Safety Analysis Due
5	Sept 17	Sept 18 Module 9 Doc Stnds 10:30-11:20 MSEE 184	Sept 19 **TCSP** Packaging 9:00-10:20 MSEE 184	Sept 20 Module 10 Software Des 10:30-11:20 MSEE 184	Sept 21 Packaging Design Due	13	Nov 12	Nov 13 User Manual Prep for Pres 10:30-11:20 MSEE 184	Nov 14 **TCSP** Eth/Env Imp 9:00-10:20 MSEE 184	Nov 15	Nov 16 Ethical and Enviro Impact Analysis Due
6	Sept 24 Lab Notebook Evaluation	Sept 25 Module 11 Assem/Solder 10:30-11:20 MSEE 184	Sept 26 **TCSP** Schematic 9:00-10:20 MSEE 184	Sept 27 Module 12 Debugging 10:30-11:20 MSEE 184	Sept 28 Preliminary Schematic and Design Narrative Due	14	Nov 19	Nov 20	Nov 21 Thanksgiving	Nov 22 Thanksgiving	Nov 23 Thanksgiving
7	Oct 1	Oct 2	Oct 3 **TCSP** PCB Design 9:00-10:20 MSEE 184	Oct 4	Oct 5 Preliminary PCB Layout and Design Narrative Due	15	Nov 26	Nov 27	Nov 28 Progress Briefings 9:00-10:20 EE 063	Nov 29	Nov 30 User Manual Due
8	Oct 8 October Break	Oct 9 October Break	Oct 10 Progress Briefings 9:00-10:20 EE 063	Oct 11 Formal Design Reviews MSEE 184	Oct 12 Formal Design Reviews MSEE 184	16	Dec 3	Dec 4	Dec 5 TCSP **PSSC Demos** 9:00-10:20 MSEE 184	Dec 6	**Dec 7** *Royal Design Showcase* **4:30-5:20 PM** **WTHR 200**

Formal Design Reviews for each team will be scheduled on 10/11 and 10/12 Final Presentation session will be on Dec. 12, 9:30–11:30 AM, in MSEE 184

Final Lab Notebook Evaluation, Confidential Peer Review, Final Report, Poster, and Senior Design Report submitted on-line by **5:00 PM, Dec. 10**

Design Project Specifications / Requirements

Work on the design project is to be completed in teams of four students. The design project topic is flexible, and each group is encouraged to pick a product that uses the strengths and interest areas of their group members. The design must have the following components:

- **Microcontroller:** To help make the project tractable, recommended microcontroller choices include Freescale, PIC, and Atmel variants. Development tools are readily available in lab to support these devices. Further, the devices themselves are relatively low cost and readily available. Optionally, auxiliary processing can be accomplished using a "motherboard". Examples of these directly supported are Intel Atom and ARM-based platforms.
- **Interface to Something:** Your embedded system must interface to some other device or devices. It could be a computer, or it could be some embedded device such as a Palm Pilot, telephone line, TV, etc. Some interface standards that could be used are: serial to a computer, parallel to a computer, Universal Serial Bus (USB), Firewire, Ethernet, Infrared (IR), Radio Frequency (RF), etc. This requirement has a large amount of freedom. To help with some of the more complex interfaces such as Ethernet, USB, or Firewire there are dedicated chips which encapsulate the lowest layers of the interface. This makes using these interfaces easier to handle but not necessarily trivial. Be sure to investigate the interface(s) you wish to utilize and make a reasonable choice. (NOTE: *Interfaces involving A.C. line current require special permission – see the instructor for details.*)
- **Custom printed circuit board:** Through the process of the design, each group will be required to draw a detailed schematic. From the schematic, a two-layer printed circuit board will be created. Board etching will be processed by the ECE Department (the first one is "free", but any subsequent iterations are the team's responsibility). The team is then responsible for populating the board (solder the parts on the board), and for completing the final stages of debugging and testing on their custom board.
- **Be of personal interest to at least two team members:** It is very difficult to devote the time and energy required to successfully complete a major design project in which you and/or your team members have no personal interest. There are *lots* of possibilities, ranging from toys and games to "useful and socially redeeming" household items, like audio signal processors and security systems.
- **Be tractable:** You should have a "basic idea" of how to implement your project, and the relative hardware/software complexity involved. For example, you should not design an "internet appliance" if you have no idea how TCP/IP works. Also, plan to use parts that are reasonably priced, have reasonable footprints, and are *readily available*. Be cognizant of the prototyping limitations associated with surface mount components.
- **Be neatly packaged:** The finished project should be packaged in a reasonably neat, physical sound, environmentally safe fashion. Complete specification and CAD layout of the packaging represents one of the project design components.
- **Not involve a significant amount of "physical" construction:** The primary objective of the project is to learn more about *digital system* design, not mechanical engineering! Therefore, most of the design work for this project should involve digital hardware and software.

Project Proposal: Each group should submit a proposal outlining their design project idea. This proposal should not be wordy or lengthy. It should include your design objectives, design/functionality overview, and project success criteria. The five success criteria common to all projects include the following:

- Create a bill of materials and order/sample all parts needed for the design
- Develop a complete, accurate, readable schematic of the design
- Complete a layout and etch a printed circuit board
- Populate and debug the design on a custom printed circuit board
- Package the finished product and demonstrate its functionality

In addition to the success criteria listed above, a set of **five significant** *project-specific* success criteria should be specified. The degree to which these success criteria are achieved will constitute one component of your team's grade.

Forms for the preliminary and final versions of your team's project proposal are available on the course web site. Use these skeleton files to create your own proposal. Note that the proposal should also include assignment of each team member to one of the design components as well as to one of the professional components of the project.

Group Account and Team Webpage: Each team will be assigned an ECN group account to use as a repository for all their project documentation and for hosting a password-protected team web page. The team web page should contain datasheets for all components utilized, the schematic, board layout, software listings, interim reports, presentation slides, etc. It should also contain the individual lab notebooks for each team member as well as the progress reports (prepared in advance of the weekly progress briefings) for each team member. At the end of the semester, each team website will be archived on the course website.

Design Review: Part way through the design process, there will be a formal design review. This is a critical part of the design process. In industry, this phase of the design process can often make or break your project. A good design review is one where a design is actively discussed and engineers present concur with the current or amended design. The design review is in some cases the last chance to catch errors before the design is frozen, boards are etched, and hardware is purchased. *A friend is not someone who rubber-stamps a design, but rather one who actively challenges the design to confirm the design is correct.*

Approach the design review from a top-down, bottom-up perspective. First, present a block diagram of your design and explain the functional units. Then drop to the bottom level and explain your design at a schematic level. Be prepared to justify every piece of the design; a perfectly valid answer, however, is applying the recommended circuit from an application note. If you do use a circuit from an application note, have the documentation on hand and be able to produce it. *Your grade for the design review will not be based on the number of errors identified in your design.* The best engineers make mistakes, and the purpose of the design review is to *catch them* rather than spend *hours of debugging later* to find them. The design review will be graded primarily on how well the group understands their design and the professionalism with which they present it.

To facilitate the design review process, the class will be split into subgroups that will meet at individually scheduled times. Both the presenters and the assigned reviewers will be evaluated.

Design Project Milestones

Each group is responsible for setting and adhering to their own schedule; however, there are several important milestones, as listed in the table below. Always "expect the unexpected" and allow for some buffer in your schedule. *Budget your time.* With proper budgeting, senior design can be a very rewarding and pleasant experience.

See course schedule for homework due dates.

Week	*Milestone*
1	Formulate project ideas Preliminary project proposal due
2	Research parts, create initial block diagram and initial BOM Final project proposal due
3	Order/sample parts, learn Eagle capture/layout
4	Create detailed BOM (including resistors, capacitors, etc.)
5	Draw preliminary schematic Prototype interface circuits
6	Finalize schematic Begin PCB layout Begin prototyping software with EVB/prototype
7	Finalize PCB layout for Design Review Continue software development Prepare for Design Review
8	Continue software development **FORMAL DESIGN REVIEWS**
9	Incorporate changes/comments from Design Review **Proof-of-Parts due** **Final schematic due** **PCB file submission due**
10	Continue software development on EVB
11	PCBs arrive - begin populating/testing
11-15	Test PCB section-by-section as parts are added, porting software as you go - *add functions one-by-one so you know what it was that "broke" your code or your board when things stop working*
16	**PSSC Demos** Prepare for Final Presentation
Finals	**FINAL PRESENTATIONS**

Learning Outcomes/Objectives and Assessment Procedures

In order to successfully fulfill the course requirements and receive a passing grade, each student is expected to demonstrate the following outcomes:

(i) an ability to apply knowledge obtained in earlier coursework and to obtain new knowledge necessary to design and test a microcontroller-based digital system
(ii) an understanding of the engineering design process
(iii) an ability to function on a multidisciplinary team
(iv) an awareness of professional and ethical responsibility
(v) an ability to communicate effectively, in both oral and written form

The following instruments will be used to assess the extent to which these outcomes are demonstrated (the forms used to "score" each item are available on the course web site):

Outcome	*Evaluation Instruments Used*
(i)	Design Component Homework
(ii)	Individual Lab Notebooks
(iii)	Success Criteria Satisfaction (general *and* project-specific)
(iv)	Professional Component Homework
(v)	Formal Design Review, Final Presentation, and Final Report

You will receive 1% bonus credit for each course outcome you successfully demonstrate. Demonstration of Outcome (i) will be based on the satisfaction of the design component homework, for which a minimum score of **60%** will be required to establish basic competency. Demonstration of Outcome (ii) will be based on the individual lab notebook, for which a minimum score of **60%** will be required to establish basic competency. Demonstration of Outcome (iii) will be based on satisfaction of **100%** of the general success criteria and a minimum of **60%** (3 out of 5) of the project-specific success criteria (PSSC). Note: *If a "motherboard" is used, at least 2 of the 3 "passing PSSC" must involve functions implemented on the custom PCB.* Demonstration of Outcome (iv) will be based on the professional component homework, for which a minimum score of **60%** will be required to establish basic competency. Demonstration of Outcome (v) will be based on the Design Review, the Final Presentation, and the Final Report. A minimum score of **60%** on the Design Review and a minimum score of **60%** on the Final Report and a minimum score of **60%** on the Final Presentation will be required to establish basic competency.

Course Grade Determination

Homework: Several "homeworks" will be assigned related to key stages of the design project. Some of the assignments will be completed as a team (0, 1, 7, 13, 15, 16, 17), three will be completed individually (2, 8, 14), and the remainder will be completed by a selected team member (one from the set {4, 5, 6, 9} and one from the set {3, 10, 11, 12}).

1. Team Building and Project Idea
2. Project Proposal
3. PCB Tutorial
4. Design Constraint Analysis and Component Selection Rationale
5. Packaging Specifications and Design
6. Hardware Design Narrative/Preliminary Schematic
7. PCB Design Narrative/Preliminary PCB Layout
8. PCB Submission, Final Schematic, and Parts Acquisition/Fit
9. Peer Review – Midterm
10. Software Design Narrative, and Documentation
11. Patent Liability Analysis
12. Reliability and Safety Analysis
13. Ethical/Environmental Impact Analysis
14. User Manual

These assignments are due on the prescribed due dates (typically Fridays) at NOON. The following penalties will be applied for work submitted late:

- 10% if submitted no more than 24 hours late
- 20% if submitted no more than 48 hours late
- 30% if submitted no more than 72 hours late
- 100% if submitted any later

15. Peer Review – Final
16. Senior Design Report
17. Final Report
18. Poster

These assignments are all due on Monday, 12/10, at 5:00 PM. Late penalties will be assessed per above late policy. However, these materials will NOT be accepted at all after 5:00 PM on Thursday, 12/13.

Grade Determination: Your course grade will be based on ***team effort*** **(40%)** as well as your ***individual contributions*** **(60%)**, as follows:

TEAM COMPONENTS (40% of total) distribution of team component:		**INDIVIDUAL COMPONENTS (60% of tot.) distribution of individual component**	
Project Success Criteria Satisfaction*	20.0%	Laboratory Design Notebook*	20.0%
Design Review*	15.0%	Design Component Report*	20.0%
Final Presentation*	15.0%	Professional Component Report*	20.0%
Final Report*	15.0%	Significance of Individual Contribution	15.0%
System Integration and Packaging	10.0%	Design Review and Final Presentation Peer Eval	5.0%
User Manual	7.5%	Confidential Peer Reviews	5.0%
Senior Design Report	7.5%	TCSP Peer Reviews (9)	5.0%
Poster	7.5%	PCB Tutorial	5.0%
PCB Proof-of-Parts	2.5%	Class Participation - Clicker Exercises	2.5%
* *items directly related to outcome assessment*		Class Participation - Team Exercises	2.5%

Your **R**aw **W**eighted **P**ercentage (RWP) will be calculated based on the weights, above, and then "curved" (i.e., mean-shifted) with respect to the upper percentile of the class to obtain a **N**ormalized **W**eighted **P**ercentage (NWP). Equal-width cutoffs will then be applied based on the **W**indowed **S**tandard **D**eviation (WSD) of the raw class scores; the minimum **C**utoff **W**idth **F**actor (CWF) used will be 10 (i.e., nominal cutoffs for A-B-C-D will be 90-80-70-60, respectively). Letter grades in the upper 30% of each range will have a "+" designation, and those that fall in the lower 30% of each range will have a "–" designation.

Course Assessment Report

Course:

ECE 477

Instructor/Submitted by:

D. G. Meyer

Please list the course Learning Objectives (Formally Course Outcomes). You can copy and paste from ECE Course Descriptions.

(i) an ability to apply knowledge obtained in earlier coursework and to obtain new knowledge necessary to design and test a microcontroller-based digital system
(ii) an understanding of the engineering design process
(iii) an ability to function on a multidisciplinary team
(iv) an awareness of professional and ethical responsibility
(v) an ability to communicate effectively, in both oral and written form

It is recommended that at least 90% of students who received a passing grade will have also demonstrated attainment of each Learning Objective.

What was your target percentage? If other than 90%, please explain.

At the senior design level, our expectation is that 100% of the students who receive a passing grade should be able to effectively demonstrate all of the learning objectives based on a passing threshold of 60%. Learning Objective 2 (based on the laboratory design notebook maintained by each student) has perennially been the most troublesome to effectively demonstrate. Frankly, this cohort was not as engaged as it should have been; hence, the unexpectedly high failure rate (15%) for Learning

At the senior design level, our expectation is that 100% of the students who receive a passing grade should be able to effectively demonstrate all of the learning objectives based on a passing threshold of 60%. Learning Objective 2 (based on the laboratory design notebook maintained by each student) has perennially been the most troublesome to effectively demonstrate. Frankly, this cohort was not as engaged as it should have been; hence, the unexpectedly high failure rate (15%) for Learning Objective #2.

In this course, what percentage of students who received a passing grade demonstrated attainment of each Learning Objective? If this is below the target percentage, please explain.

Average Outcome Scores and Outcome Demonstration Statistics for ECE 477

Outcome # 1 Avg Score: 79.4% Passed: 20/ 20 = 100.00% Failed: 0/ 20 = 0.00%

Average Outcome Scores and Outcome Demonstration Statistics for ECE 477

Outcome # 1 Avg Score: 79.4% Passed: 20/ 20 = 100.00% Failed: 0/ 20 = 0.00%

Outcome # 2 Avg Score: 77.1% Passed: 17/ 20 = 85.00% Failed: 3/ 20 = 15.00%

Outcome # 3 Avg Score: 80.0% Passed: 20/ 20 = 100.00% Failed: 0/ 20 = 0.00%

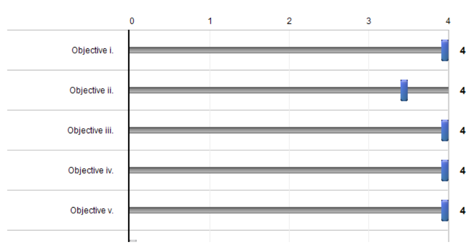
Outcome # 4 Avg Score: 87.9% Passed: 20/ 20 = 100.00% Failed: 0/ 20 = 0.00%

Outcome # 5 Avg Score: 82.1% Passed: 20/ 20 = 100.00% Failed: 0/ 20 = 0.00%

Demonstrated all five outcomes based on primary assessment: 17/ 20 = 85.00%

The expectation is that students who successfully complete a course will demonstrate adequate attainment of each of the course's Learning Objectives.

On a scale from 0 - 4 (0 = not at all, 1 = marginal, 2 = adequate, 3 = good, 4 = very good), please rate the overall extent to which the students in this course have demonstrated attainment of each of the Learning Objectives.



Are the Learning Objectives appropriate? If not, explain.

yes

Are the students adequately prepared for this course and are the course prerequisites and co-requisites appropriate? If not, explain.

yes

Do you have any suggestions for improving this course? If so, explain - especially if the overall attainment of the course Learning Objectives did not meet your expectations.

MORE LAB SPACE!

MORE FACULTY INVOLVEMENT!!

Appendix A:

Senior Design Reports

Purdue ECE Senior Design Semester Report

Course Number and Title	ECE 477 *Digital Systems Senior Design Project*
Semester / Year	Fall 2012
Advisors	Prof. Meyer and Dr. Johnson
Team Number	1
Project Title	AutoCart

Senior Design Students – Team Composition			
Name	**Major**	**Area(s) of Expertise Utilized in Project**	**Expected Graduation Date**
Shi Jia	CmpE	Microcontrollers	5/2013
Tom Pollard	CmpE	Software	12/2012
Andrew Senetar	EE	Power Design / Enclosures	5/2013
Yixin Wang	EE	PCB Design	5/2014

Project Description: Provide a brief (2-3 page) technical description of the design project, as outlined below:

(a) Summary of the project, including customer, purpose, specifications, and a summary of the approach.

The AutoCart is a project to construct a self-driving go-kart with remote control and drive-by-wire capabilities. It is targeted towards go-kart enthusiasts with an interest in the relatively new field of automated consumer automobiles. The specific purpose of this project is to integrate automation into an existing go-kart chassis. Aside from the frame, wheels, and pre-packaged motors, the go-kart was assembled from individual parts, ICs, and PCBs. The AutoCart is a driven by a 12kW BLDC motor for propulsion and two auxiliary linear actuators to realize steer-by-wire and brake-by-wire. Vehicle power is sourced from 72V stacks of LFP batteries. The 72V bus is stepped down to 12V and 3.3V to supply the Atom Board and vehicle electronics. Vehicle electronics consist of five discrete MCUs on PCBs networked using the CAN 2.0B protocol and an Atom board interfaced to the CAN bus through a USB/UART port. The sinusoidal drive motor control board uses an existing Hall-effect PMSM drive control library, but the remaining vehicle controllers are written in-house. For vehicle automation (i.e. lane detection and obstacle detection), the AutoCart's software uses OpenCV for image processing.

(b) Description of how the project built upon the knowledge and skills acquired in earlier ECE coursework.

The AutoCart project encompasses a variety of subjects in the electrical and computer engineering field. PCB design requires a thorough knowledge of linear circuits and transistors, even more so for motor driver circuits. Assembling PCBs and discrete packages builds on soldering and power-tool skills from prior projects. Any mistakes in the original design were fixed using PCB modification techniques honed in during the ECE 362 mini-project. Familiarity with reading data sheets is also necessary to ensure that in-house circuits are electrically compatible with packaged ICs such as microcontrollers and drivers, and that in-house software peripheral drivers meet the specifications of said peripherals.

MCU software development builds on the peripheral interfacing experience from ECE 362, as well as software development skills from C programming classes.

(c) Description of what new technical knowledge and skills, if any, were acquired in doing the project.

The AutoCart required knowledge of several subjects which are not in Purdue's general ECE curriculum. The most advanced of these was the automated image analysis and driving software. Implementation of the software required learning how to work with large software libraries to implement complex and experimental techniques. The knowledge of working with C in an embedded interrupt-driven environment was acquired. Because the vehicle electronic control software codebase spans five boards, the use of a high-level language for embedded programming was necessary, but the abstraction creates pitfalls such as compiler optimizations changing the intended function of the code. The ability to implement advanced motor control methods was also acquired. BLDC motors, unlike simple brushed motors, cannot be driven by applying single PWM waveform to its terminals; software drivers must switch the PWM input to generate a rotating magnetic field to spin the motor.

(d) Description of how the engineering design process was incorporated into the project. Reference must be made to the following fundamental steps of the design process: establishment of objectives and criteria, analysis, synthesis, construction, testing, and evaluation.

The engineering design process was incorporated into every part of the AutoCart project. First, the team selected a project subject and formulated five project specific success criteria for the subject. Then, project requirements, budget, and availability were analyzed to select components. Once the Bill of Materials was completed, work on PCB and software design began. After components arrived and the PCBs were completed, an iterative process of parts assembly, testing, evaluation, and modification was repeated until the finished PCB was fully functional and met project requirements.

(e) Summary of how realistic design constraints were incorporated into the project (consideration of <u>most</u> of the following is required: economic, environmental, ethical, health & safety, social, political, sustainability, and manufacturability constraints).

Economic: The AutoCart is built out of modestly priced parts. Aside from the main BLDC motor and associated drivers, the go-kart can be considered low-cost. The chassis consists of painted steel tubes supporting a plastic tub chair. The drive assembly, aside from the motor, consists of a simple disk brake and a fixed-ratio chain transmission. Power is supplied through two boxes of LFP batteries, which are up to 80% less expensive than common lithium ion batteries but typically have 50% lower energy densities. Because the LFP batteries are rated for higher charge/discharge cycles, the lifetime cost will be lower.

Environmental: Aside from trace amounts of lead and heavy metals in the assembled PCBs, and the pollutants generated in the process of manufacturing them, the AutoCart go-kart is relatively environmentally sound for an electric vehicle. While manufacturing and disposal of the battery is often a concern, LFP batteries have longer lifetimes than standard lithium-ion batteries and do not contain cobalt, so the hazard from improper disposal is minimized.

Ethical: Although this project incorporates automation capabilities into a vehicle, it is the human driver that is ultimately responsible for the vehicle. Thus the AutoCart has inputs which keep the go-kart from entering remote operation mode and includes overrides which transfer control back to the human driver as smoothly as possible.

Health & Safety: The go-kart has many powerful moving parts and a 72V power bus which may be exposed to the operator. The linear actuators for steering and braking can provide significant mechanical force, and so their operation must be quickly switched off within 10ms of pressing any of the manual override switches. The 72V bus will be enclosed within a Plexiglas housing to prevent accidental contact and short-circuits. In the event that a short does occur, the high-voltage contactor or the 200A fuse will cut power to the system. In the event of sudden acceleration or a roll over, seat belts secured to the go-kart frame and a roll-cage will protect the passenger from injury.

Social: Although the social impact of a go-kart designed for a niche racing sport is limited in scope, the use of a sinusoidal motor controller and high frequency PWM minimizes the noise pollution generated by the vehicle.

Political: The operation of this go-kart will be intended for racing tracks and private lands. No considerations for street legality were made in the planning and construction of the vehicle.

Sustainability: Aside from the pollutants generated by the manufacturing of PCB and the batteries, many components of the go-kart are recyclable. The metal frame can be recycled/reprocessed; the copper power cables can likewise be reused; the LFP batteries contain common elements and can be recycled if necessary.

Manufacturability: In the design and construction of the go-kart, component placement was heavily influenced by the ease of mounting. Thus the assembly of the go-kart was straightforward wherever possible. The area near the BLDC motor was difficult to access and assemble, but placing components there was influenced by the necessity of not creating high-power antennas.

(f) Description of the multidisciplinary nature of the project.

The AutoCart team consisted of two EE and two CompE majors. Because the go-kart has many design components, each team member handled their own area of expertise. One member was primarily responsible for product packaging and played an advisory role in the construction of the PCBs. Another member focused on PCB design and assembly, due to his previous experience in using Eagle and soldering. Another member was solely responsible for developing the MCU software. The final member was primarily responsible for developing the go-kart automation and assisted with packaging and PCB assembly. The AutoCart project is thus not only multidisciplinary, but also each member is highly specialized.

(g) Description of project deliverables and their final status.

- Daughter board – networked and fully functional. Returns GPS, telemetry, and accepts commands from the Atom board
- Safety board – networked, fully functional, and mounted. Indicator LEDs can be driven to desired states, but many headers are not yet connected to their intended sensors
- Steering board – networked and fully functional. Capable of remote control and driving the steering actuator
- Braking board – networked and fully functional. Capable of remote control and driving the braking actuator
- Motor control board – networked. Still need to verify functionality of the three-phase motor drivers
- Atom board – networked and fully functional. Remote control is possible through TCP/IP. Line following is partially functional, obstacle detection is being worked on

Purdue ECE Senior Design Semester Report

Course Number and Title	ECE 477 *Digital Systems Senior Design Project*
Semester / Year	Fall 2012
Advisors	Prof. Meyer and Dr. Johnson
Team Number	2
Project Title	The Mind Reader

Senior Design Students – Team Composition			
Name	**Major**	**Area(s) of Expertise Utilized in Project**	**Expected Graduation Date**
Matt Waldersen	EE	Circuit Design/Circuit Debug	Spring 2013
Taylor Strzelecki	CmpE	Hardware Design/Software	Fall 2012
Rick Schuman	CmpE	Software (Micro/BeagleBoard)	Fall 2012
Krishna Jhajaria	CmpE	Software	Fall 2012

Project Description: Provide a brief (2-3 page) technical description of the design project, as outlined below:

(a) Summary of the project, including customer, purpose, specifications, and a summary of the approach.

The Mind Reader is a mobile computing platform that utilizes an electo-oculargram (EOG) and an electroencephalogram (EEG) to create a mobile brain computer interface (BCI). The Mind Reader uses inputs from the EOG, EEG and an external camera to create a virtual reality display, which is overlaid with various applications and displayed for the user on a pair of commercially available video glasses. The user is able to navigate between applications using eye gestures (look left or right). The signal received from the eye movements is filtered and amplified by analog circuitry, then digitized by an external analog-to-digital converter module (ADC), and converted to left or right commands via a K-nearest neighbor algorithm on a dsPIC microcontroller. Once the user has navigated to an on-screen application, they are able to select an application by simply concentrating on it. The user's level of concentration will be determined by a commercially available NeuroSky EEG. The NeuroSky Mindwave is capable of returning levels of concentration and meditation, which are computed and averaged on the device on a zero to one hundred scale. The Mind Reader will retrieve this data via a universal asynchronous receiver/transmitter (UART) connection implemented on a dsPIC microcontroller communicating with the Neurosky wireless dongle. This device is designed for all users who are interested in mobile computing and want to make an attempt at future technology.

(b) Description of how the project built upon the knowledge and skills acquired in earlier ECE coursework.

The Mind Reader required knowledge from many previous courses that our team members have gained during their studies at Purdue University. The most relevant coursework to our project was in ECE 362, Microprocessor System Design and Interfacing. The Mind Reader contains a microcontroller as the main unit for data transfer and processing contained in the project. The Mind Reader also contained complex filters and amplifiers that built on knowledge obtained from ECE201 and ECE202. Our BeagleBoard application required the knowledge from previous programming classes in the ECE curriculum as well as object

oriented classes taken from the CS department and multithreaded programming from experience in industry. Our project also contained hardware design and debugging which involved experience from past classes including ECE 270, ECE207, and ECE 208.

(c) Description of what new technical knowledge and skills, if any, were acquired in doing the project.

This project gave our team the opportunity to learn new technical knowledge including printed circuit board layout, soldering techniques, web page design, and embedded design. Before beginning work on the project, our team had no experience with printed circuit boards and very little experience with soldering, web page design, and embedded operating systems. While web page design may have been a small subsection of the project, to keep track of our project's progress, all other knowledge gained was vital to the correction functionality of our device.

(d) Description of how the engineering design process was incorporated into the project. Reference must be made to the following fundamental steps of the design process: establishment of objectives and criteria, analysis, synthesis, construction, testing, and evaluation.

The Mind Reader began as an idea to create a mobile brain computer interface that would be able to trace eye movements and read the users mind to complete tasks. The idea seemed farfetched at first, but our team developed a set of realistic goals to accomplish during this project. Using these goals, the team developed an updated device that we felt was realistic for a semester long project, a mobile computing platform that allowed the user to navigate via eye gestures and select by raising their level of concentration. Our team then determined a list of suitable devices that would make up our device based on an analysis of the goals of the project. We decided on using a dsPIC microcontroller, BeagleBoard, Vuzix video glasses, an EEG, and an EOG to be the main components of our system. Once the components were determined the team set out to create a schematic of the device that included all of the main components along with peripheral devices need to communicate between the main components. This schematic was then translated into a printed circuit board, that was optimized though many trial and error layouts until the team was satisfied with the results. When the PCB arrived back from manufacturing, the boards needed to be populated with all components and testing of the circuit commenced. Our team ran into issues with power supplies as well as the reset circuit on the main board, which both needed to be redesigned and reconstructed. Our final product was looked at as a successful prototype, although there are many design changes that would be considered for a second revision, the device none the less was a success.

(e) Summary of how realistic design constraints were incorporated into the project (consideration of <u>most</u> of the following is required: economic, environmental, ethical, health & safety, social, political, sustainability, and manufacturability constraints).

Economic: Economic costs were taken into account often during the development of the Mind Reader. The major components of the Mind Reader (Video Glass, EEG, Microcontroller, BeagleBoard) consisted of most of the cost of the project. Since the product is on the forefront of BCI development the product would be able to turn a profit.

Environmental: We have taken into account the environmental impact of our device which mainly is a concern with the lithium-ion battery. Other considerations during the manufacturing phase of the project were taken into account, including PCB manufacturing, soldering, and integrated circuit manufacturing.

Ethical: Ethical constraints were also taken into account to assure that the user would be safe during the operation of the device. We needed to assure that any consumer using the device would be at no risk for their health during use or no negative effects on the user's health in the future due to the use of our device.

Health & Safety: Health and safety constants were taken into account to assure that the user would be safe during the operation of the device. The user is connected to a complex analog circuit via electrodes placed on the user face. We needed to assure that there is no chance of the circuit running current through the user's skin. We also took into account the use of RF signals close to the user's head and how this could affect the user's health.

Social: While looking at the social impact the Mind Reader would have on the population, our team looked into how the device would be used and the effects that the device could have on how the population social interacts. The Mind Reader has the potential to greatly affect the population from a social standpoint, because of its new aged methods of interacting with a computing system.

Political: The political constraints taken into account for the Mind Readers development mainly consisted of research into current patents that were filed that contain functionality that the Mind Reader also contains. We needed to be sure that if our device were to be taken into a manufacturing state that the team would be free of legal trouble that may be accompanied with manufacturing the Mind Reader.

Sustainability: Sustainability issues were discussed briefly with our team during the design phase of the Mind Reader. The sustainability issue was also covered in depth on the reliability and safety analysis paper.

Manufacturability: Manufacturing was discussed along with the cost of the project, and patent analysis. The Mind Reader would be suited to be manufactured if the demand for our product would outweigh the costs. The cost of the designing the Mind Reader is economically expensive, but as stated the retail price of the product should be able to compensate for the increased production costs.

(f) Description of the multidisciplinary nature of the project.

The development of the Mind Reader required knowledge for multiple disciplines consisting of computer engineering, electrical engineering, and biomedical engineering. The Mind Reader brought together these three main disciplines to create a mobile brain computer interface. An understanding of the biomedical side of engineering was needed to correctly develop a circuit that can be used to track eye gestures as well as an understanding of how an EEG and EOG work. The use of electrical engineering was needed for complex filter and amplifier design for the eye gesture circuit. Computer engineering knowledge was prevalent in the applications software that was written as well as the microcontroller communication protocols.

(g) Description of project deliverables and their final status.

The Mind Reader in its final state is a head mounted mobile computational platform. The device captures a live video feed from the front of the user and displays the video stream with overlaid applications and graphics for the user on a pair of video glasses. The user is able to select applications based on their attention levels. A rise in attention over a period of time is sensed by an EEG and information is transferred to a dsPIC microcontroller where it is passed through a selection algorithm. The device also contains a circuit that can accurately filter and amplify eye gestures. The external analog-to-digital converter was not functional by the end of the project so the user is unable to move in the virtual reality display.

Purdue ECE Senior Design Semester Report

Course Number and Title	ECE 477 *Digital Systems Senior Design Project*
Semester / Year	Fall 2012
Advisors	Prof. Meyer and Dr. Johnson
Team Number	3
Project Title	Piano Glove

Senior Design Students – Team Composition			
Name	**Major**	**Area(s) of Expertise Utilized in Project**	**Expected Graduation Date**
Carolyn McMican	EE	Hardware/Software Design	May 2013
Daniel Stein	EE	Hardware/Software Design	December 2012
Jonathan Kuntzman	CmpE	Software Design	May 2013
Mihir Shah	CmpE	Software/Packaging Design	December 2012

Project Description: Provide a brief (2-3 page) technical description of the design project, as outlined below:

(a) Summary of the project, including customer, purpose, specifications, and a summary of the approach.

The Piano Glove allows a user to play a virtual keyboard on any flat surface, using a glove and a stationary base unit. The final product is aimed primarily at children, for use as a toy. The glove contains pressure and stretch sensors, which will detect finger motion. This data will be digitized and pre-processed on the glove, with the data sent via an RF transceiver to the base unit. The base unit will receive this data and combine it with data from the base station's ultrasonic distance sensor to determine the correct note and volume that have been played by the user. The base unit will output this data using a sound synthesis chip and a 3.5mm speaker jack. It will also be able to output data to an LCD display mounted in the case.

(b) Description of how the project built upon the knowledge and skills acquired in earlier ECE coursework.

This project has allowed us to make use of knowledge gained through ECE courses. In courses like ECE 270 and ECE 362 we learnt how to program in assembly and microcontroller programming. We learnt circuit analysis and design in ECE 255, ECE 208 and ECE 207. We learnt signals and systems in ECE 301. Although we had learnt all the concepts in theory and applied some of them in labs, this project more or less made sure we applied whatever we learnt in last 3 years and more. Our team consisted of two computer engineers and two electrical engineers. By the of this project, the two computer engineers got more hands on experience in circuit building like the making of PCB whereas the two electrical engineers got more hands on experience in software programming the sensors as well as the microcontrollers. Throughout the last few years, we were not taught programming sensors and how to read in their values and then merge that with the project. In this project, we learned how to make use of the force sensors and stretch sensors. We learnt how to use their values and transmit them through transceivers and communicate between microcontrollers. Overall, this project has given us a real-world experience of all

the things we have learned through our coursework. It not only taught us team-building but also how to approach any problems we might face during our task.

(c) Description of what new technical knowledge and skills, if any, were acquired in doing the project.

During the course of this semester, several new technical skills have been developed. Some members of the team learned how to use Eagle to lay out schematics. In addition, some members learned how to lay out PCBs, as well as certain design considerations which should be made when doing so. Some members also learned how to solder and assemble PCBs. Finally, all members learned to utilize MPLAB X and the IDC3 to develop software and program PIC18 and PIC24 microcontrollers.

(d) Description of how the engineering design process was incorporated into the project. Reference must be made to the following fundamental steps of the design process: establishment of objectives and criteria, analysis, synthesis, construction, testing, and evaluation.

The engineering design process that was incorporated in the design of the Piano Glove allowed for the completion of project specific success criteria (PSSCs). After the formation of PSSCs, the project was split into multiple steps: design constraint analysis, component selection, schematic design, printed circuit board (PCB) layout, software design, PCB population, software and hardware testing. Each step advanced the project toward completion and was required in order to move onto the next step.

Objectives for each PSSC were thought out carefully in order to assure each goal addressed a critical part in the completed project. An analysis of design constraints was made and scrutinized so that proper component selection could be made. Components were selected to ensure that sound production computations were achieved in less than 10ms. Schematic design was essential to ensure a properly working circuit for PCB layout. Software was written to address the key elements required to be achieved by the Piano Glove. Preliminary software was tested on development boards. PCB was populated with necessary components where final testing of hardware and software marriage could be achieved. Evaluation involved testing for the completion of each PSSC.

(e) Summary of how realistic design constraints were incorporated into the project (consideration of <u>most</u> of the following is required: economic, environmental, ethical, health & safety, social, political, sustainability, and manufacturability constraints).

Economic: This product was designed to be sold for relatively small amounts of money, since it is primarily a toy. We went for fairly cheap components in the building of our project, so that it could be sold cheaply.

Environmental: The main environmental constraint of our product was power consumption. To help with these constraints, we chose low power components, and we decided to run our microcontrollers at the lowest possible clocking frequency.

Ethical: Our main ethical constraint was to build a product that would not have a high premature failure rate. We chose fairly high quality components to help prevent these failures.

Health & Safety: The health and safety of a user of our product is always a main concern. However, our product does not have any large health and safety dangers, so we did not need to incorporate many constraints based off of this.

Social: The social constraints of our product are to produce an entertainment product. The product should be fun and simple to use.

Political: The only political constraints of our product it to make sure it complies with all state and federal laws that applies to it.

Sustainability: Our product would need to survive everyday use by users in a wide age spectrum. This would require making a product that can sustain daily wear and tear.

Manufacturability: The product would require the manufacturing of two main parts: the manufacturing of the glove unit and the manufacturing of the base unit.

(f) Description of the multidisciplinary nature of the project.

The design and implementation of the Piano Glove incorporates electrical and computer engineering, as well as the expertise of a pianist. Electrical engineers design the analog to digital circuitry needed as well as sound production. Computer engineers ensure that digital components work as desired, with emphasis on the microcontroller and embedded software required for it to work. The expertise of a pianist is important for the design and implementation of haptic interface. This is to ensure that the glove is comfortable and suitable for play.

(g) Description of project deliverables and their final status.

- The ultrasonic Ping is working correctly: we can measure the distance to the glove using the Ping connected to the dev board
- The force and pressure sensors have been successfully read by the glove micro ATD channels and formatted for use by the base micro
- The SpeakJet chip has been successfully used to create sounds using the dev board

Purdue ECE Senior Design Semester Report

Course Number and Title	ECE 477 *Digital Systems Senior Design Project*
Semester / Year	Fall 2012
Advisors	Prof. Meyer and Dr. Johnson
Team Number	4
Project Title	Automated Coffee Roaster

Senior Design Students – Team Composition			
Name	**Major**	**Area(s) of Expertise Utilized in Project**	**Expected Graduation Date**
Ethan Price	CmpE	PCB, Programming	December 2012
Shicheng Guo	CmpE	Programming, Hardware Design	May 2013
Kyle Haver	CmpE	Programming	December 2012
Wesley Tso	CmpE	Programming	December 2012

Project Description: Provide a brief (2-3 page) technical description of the design project, as outlined below:

(a) Summary of the project, including customer, purpose, specifications, and a summary of the approach.

The automatic coffee bean roaster is a modified popcorn popper used to roast coffee beans automatically, through the monitoring of the coffee beans in the roasting area. The popper itself acts as the roasting unit and is mounted on top of a project box, which contains all the non-sensor components of the device. The box has a 2x16 LCD display and three push buttons as a way to operate the device. On top of the roasting unit, there is the roasting cover, with a smaller project box containing all the sensors mounted on top of the roasting area. There will be a collection of wires running from the bottom of the roasting unit, where the power cord used to come out of, up to the project box and its sensors. The target audience will be people that want to take the entire coffee making process into their own hands, as this is one of three steps used to make coffee. Also, the roaster is designed for indoor use on a flat surface, as the device does not complete the coffee-making process.

(b) Description of how the project built upon the knowledge and skills acquired in earlier ECE coursework.

There was a lot of prior information that was needed to succeed in the creation of the coffee roaster. The first major skill needed was circuit analysis, which was taught early on in the ECE curriculum. This was used to find values the team needed to find capacitor and resistor values during circuit design and while formulating the constraints for the project. The respective labs for the courses also helped the team become familiar with the use of signal measuring equipment to analyze the circuit when it came to troubleshooting. The classes on digital systems design and microprocessors that were taught later on in the curriculum helped the team get a better understanding of integrated circuits and microprocessors. In addition, the microprocessor class taught the basics of soldering, which was used extensively in the project creation. The class also started the trend of having final projects in the curriculum, which was a great introduction to putting together ECE knowledge for a self-decided project, and was very much like an shortened version of the senior design project creation. A lot of the programming courses were very useful as

well because the team's microcontroller programming used the Arduino software stack, which needed to be programmed in C.

(c) Description of what new technical knowledge and skills, if any, were acquired in doing the project.

There were many new technical skills learned during the completion of this project. This was one of the first classes to introduce the topic of PCB design, which includes many different facets and pitfalls. Going through the process of designing and testing a custom PCB was a valuable learning experience. It also required a fair amount of soldering, which has been somewhat practiced in the ECE curriculum, but not to the extent that it was on this project. Besides hardware skills, this project also exposed the team to several new software skills, including working with the Processing environment and AVR programming. The Processing environment was where the majority of the project code was written, and while it uses a language very close to C++, there are also many new libraries and slightly different coding conventions. Programming for the Hacrocam was done in C, which the team already has experience with, but it also required the intermediary step of programming the device using AVR software. This provided exposure to the various tools and methods used to program these devices. As the project was completed there were also numerous errors and bugs that needed to be fixed, both in hardware and software. The skills developed to be able to identify and remedy these errors were also invaluable to the team success and will surely be used again in the future.

(d) Description of how the engineering design process was incorporated into the project. Reference must be made to the following fundamental steps of the design process: establishment of objectives and criteria, analysis, synthesis, construction, testing, and evaluation.

While much of the design process was enforced for the team due to the schedule of the class, the engineering design process was followed to assist with a proper implementation of the project. Establishment of the team's objectives and criteria came into consideration before the team even decided on what project to work on for the class. Because of the requirement to have five project specific success criteria for the project, the difficulty of the criteria became a large factor in the decision of what project the team would go forth with. The primary reason the team chose to work on the coffee roaster idea was because the project idea was the one that the team had the best idea of how to implement. Analysis and synthesis were the next major steps for the creation of the coffee roaster, a lot of which was poured into circuit design and PCB creation based of the schematic. All the code for the microcontroller was done during these steps as well. Because of the detail of work that was done during the previous steps, the actual construction of the project was pretty straightforward and was done fairly quickly. However, the testing stage for the devices took much more time. The code and circuitry needed to be reworked a number of times during the stage, and the programming had to be rewritten a few times as well. Due to the deadline on hitting the evaluation stage, the testing stage was cut short of doing complete tests and a lot of the evaluations were done based off the operation of the individual sensors over the evaluation of the project as a whole.

(e) Summary of how realistic design constraints were incorporated into the project (consideration of most of the following is required: economic, environmental, ethical, health & safety, social, political, sustainability, and manufacturability constraints).

Economic: One of the biggest constraints that the team was considerate of during the creation of the roaster was the cost of the components. Because the roaster was meant to be a household appliance, the team decided that the best course of action would be to make manufacturing cost of the roaster as low as possible so it would be affordable for consumers.

Environmental: Unfortunately, a lot of the environmental issues with the product pertained to the manufacture and disposal of the electronics and PCB, which were all out of control. However, the team made sure that all of the components that were used for the popper were RoHS compliant. While the roaster was drawing a lot of power from the outlet, the amount of electricity needed to operate the device could not be lowered due to the amount of heat needed to roast the beans and the approach that was being taken for the roasting process.

Ethical: The ethical concerns for this project are focused on the safe operation of the device. Providing a dangerous appliance to the consumer that could damage their house or the user would be very unethical.

Health & Safety: The primary health and safety constraints that were considered for the project were based off of the potential accidents that could happen while operating the roaster, which mostly pertained to potential fire hazards. Due to the high amount of heat coming out of the roaster, it was important that little to no harm would come to the user during the operation of the device.

Social: The final product needed to be simple enough to use that anyone could operate the device. It also needed to look good enough that the consumer would be okay with keeping it in their kitchen.

Manufacturability: Since this would be a mass-produced device it was necessary to keep all of the components relatively simple and limit the use of specialized hardware.

(f) Description of the multidisciplinary nature of the project.

This project incorporated the majority of the curriculum from the ECE department, starting with basic circuit design and gong all the way to algorithms and coding. The initial steps of the project focused on the hardware design of the project, which used the skills of the team to select appropriate components based on their behavior and datasheets. Once they were selected, the components had to be integrated into the circuit, including all of the additional hardware required to make them work. This includes the addition of decoupling capacitors, current-limiting resistors, and other components, which were selected based on the calculated parameters. Designing the PCB required both circuit analysis skills and knowledge of the electrical behavior within the PCB circuit. After the PCB was fabricated debugging the hardware was done using the signal analysis and laboratory skills that have been developed throughout the ECE curriculum. With all of the hardware working the final part was coding the software that would provide the logical interface between all of the components. This required a great deal of coding, using many different resources and tools,

to create the final software and debug it. Experience with microprocessors and c-based languages were especially important to this last step.

(g) Description of project deliverables and their final status.

The final automated roaster is operation though it has been modified slightly from the initial proposal. The roaster has met all of the PSSCs set by the team but some of the secondary functionality has been limited, including the microphone and the rotary encoder. The microphone is no longer used to detect the cracks, due to the level of background noise, and the rotary encoder has been replaced by three pushbuttons. It was also found that the camera chosen would probably not provide the color depth needed to be able to detect subtle changes in the coffee beans; it is still able to detect the general color and is still useful as a dangerous condition detector. With these changes the roaster is still able to monitor the roast of the beans automatically to get to the level chosen by the user.

Purdue ECE Senior Design Semester Report

Course Number and Title	ECE 477 *Digital Systems Senior Design Project*
Semester / Year	Fall 2012
Advisors	Prof. Meyer and Dr. Johnson
Team Number	5
Project Title	Sports Telemetry

Senior Design Students – Team Composition			
Name	**Major**	**Area(s) of Expertise Utilized in Project**	**Expected Graduation Date**
Ashley Eidsmore	EE	Biomechanics, Packaging	Spring 2013
Jake Gilfix	EE	Software, Wireless	Spring 2013
Kayode Adeniji	CmpE	PCB Design, Hardware	Fall 2012
Brendan Claussen	EE	PCB Design, Hardware	Spring 2013

Project Description: Provide a brief (2-3 page) technical description of the design project, as outlined below:

(a) Summary of the project, including customer, purpose, specifications, and a summary of the approach.

The Sports Telemetry Device has been created as a tool to help researchers collect more precise data on brain injuries to athletes playing contact sports. It is a small head mounted device that contains multiple accelerometers and gyroscopes placed in one of three places: the back of the head, behind the right ear and behind the left ear. This allows for a very accurate description of actual head and brain movement while being tackled or hit. This project was motivated by previous devices used by some researchers that have been substandard. Other devices may provide data from bad or misplaced sensors, and in some extreme cases, would not even provide the raw sensor data that the researchers need. Sports Telemetry Device aims to correct all of these difficulties neurotrauma researchers face.

(b) Description of how the project built upon the knowledge and skills acquired in earlier ECE coursework.

From day one, our team had been using vast amounts of previous knowledge gained in the ECE curriculum. When choosing components we had to examine datasheets thoroughly taking into consideration factors such as DC noise margin (ECE 270) to ensure proper function of our parts. In designing our power supply we found a problem with the recharging process by using circuit analysis (ECE 201). To guarantee our power supply and battery recharge would not interfere with one another we developed a workaround with a low voltage dropout Zener diode (ECE 255/305). Choosing and interfacing to our microprocessor required knowledge from ECE 362, while debugging our completed circuits needed previous experience with measuring equipment such as oscilloscopes and digital multi-meters (ECE 207/208). Many of the core ECE classes were put to the test in designing our system.

(c) Description of what new technical knowledge and skills, if any, were acquired in doing the project.

The course began first by teaching us how to design and layout circuit boards in Orcad which our team was not familiar with. There are various aspects of a PCB that our team had to learn along the way such as capacitor placement, trace size and various lessons about ground planes. We also had to interface with a radio frequency Zigbee module which was an entirely new concept to the team. A highly sensitive RF chip requires a lot of planning and consideration in the PCB design. Board size, IC placement and via placement were all effected by the Zigbee module. When we decided to use a NAND flash to store our data we had to learn the ins and outs of NAND flash, both the hardware and software side. We did not use a premade solution to interface to the NAND, but rather preformed all communication with our microprocessor giving us great insight how NAND flash memory operates. Our project also supports USB connection to a laptop which has been an incredibly enlightening experience. None of our team had any idea how complex talking over USB could be. All of these components, along with our many sensors, had to be small enough to fit on the back of a human head without discomfort. This made all of our components incredibly small and very difficult to work with which in turn taught us how to deal with and solder tiny pins/pads.

(d) Description of how the engineering design process was incorporated into the project. Reference must be made to the following fundamental steps of the design process: establishment of objectives and criteria, analysis, synthesis, construction, testing, and evaluation.

Our team knew we needed to capture data, store data then output the data via a reliable method in a safe fashion. There was no compromising on those core requirements. With that in mind we also knew that all of our parts had to be low power and small form factor. These were the considerations in creating our part selection. After the sensors NAND flash and USB were chosen to accomplish our core criteria, we also decided to implement a wireless feature into our product to allow for real-time data transfer while the athlete was actually experiencing possible brain trauma. The method of transfer required a discussion into what method should be used. Topics such as cloud storage, Bluetooth and Zigbee were brought up. In the end we determined the lowest power and most efficient method of transfer was Zigbee.

Our boards arrived with some errors (not board fabrication errors but layout errors) that needed correction and eventually we sent off for a new set of boards. A small setback as we were able to begin testing our code on a development board without working boards. We incrementally tested each code module as it was finished instead of compiling all the functions onto one processor and testing it. This allowed for easy demonstration of PSSCs in a one by one fashion. By the semester the team was divided in half, hardware/packaging and software. The hardware/packaging team populated the boards, debugged hardware problems and built the electrical housing while the other team working on software constantly developed and tested the code on the development board. This method reached a critical moment when combining the two team's results together by putting the code on the working board. It did not work the first few tries but after a couple days of debugging we were finally able to get a working board with our PSSCs working.

(e) Summary of how realistic design constraints were incorporated into the project (consideration of most of the following is required: economic, environmental, ethical, health & safety, social, political, sustainability, and manufacturability constraints).

Economic: Beginning the semester we believed we could be making Sports Telemetry Device into an actual commercial product to compete with similar existing devices. To accomplish this we considered the market implications of each function we included and how it would affect issues such as pricing, efficiency and safety. The pricing component is dependent upon component selection and ease of board fabrication/assembly. While the behind the head board a fairly complex layout, it could not be simplified any more in the constrained space it has. The base station was designed to be fairly straightforward with minimal parts and board space needed. The component selection was also designed to be low power to allow for extended use on the sports field which would give the device more value than other competitors.

Environmental: Sports telemetry device consumes very little power at approximately 70mA at its most active (behind the head board). A capacitive sensor is also in place to provide extra power savings when the device is not in use. The battery has the ability to provide enough power for roughly 6 hours on the head mounted board. This coupled with the battery's guaranteed 300 recharge life cycle comes out to approximately 1800 hours of use on a single battery lifetime. The NCAA limits players, no matter the sport, to spend no more than 20 hours a week on their sport. Even if the player spends the absolute maximum amount of time on the field it would still last 90 days before the battery needs to be discarded. This limits the amount of Lithium polymer batteries the consumer would discard into the environment. In our user manual we have gone into detail on how the consumer should discard our components if needed.

Ethical: Testing is absolutely essential when considering ethical implications. Our team has to be completely confident that our device cannot harm a user of our device. Not only physical implications, such as if the board breaks under the stress of a tackle, but the data needs to be accurate as well. If coaches or trainers are using our product they may rely on the data our device produces to judge whether a player has sustained injury. If our data is wrong this could have severe consequences.

Health & Safety: Sports Telemetry Device has many factors to ensure user safety. The batteries used in the device have been selected only from a producer that has rigorously tested their battery under very extreme conditions. Our lithium polymer battery has been proven to not catch fire or leak acid under any (foreseeable) circumstance our device will be in. Our head mounted device was designed to have not male pins protruding anywhere to avoid sharp points. The base station has been given a cover to protect it from rain or any person reaching into the electronic connections. All of the parts in the circuitry were analyzed for its reliability and we found that even our most failure prone part (TPS62203 Switch mode regulator: 19.5 failures/10^6 hours) was still a very reliable part considering the reliability was calculated with such extreme forces and temperatures that humans would not likely survive in.

Social: Developing a reliable tool to provide data on concussions could shed more light on problems currently afflicting sports such as football. Terrible events have occurred within the past couple years alone related to concussions. Researchers know that multiple sustained concussions can lead to many chilling side effects such as depression or even suicidal tendencies. More in depth research into brain trauma is absolutely needed especially with the popularity of football in America. We believe a device like to Sports Telemetry Device can help research groups studying these effects.

Political: Someday in the future there could be a possibility that concussion research will change rules within sport associations like the NFL, however that was not a factor when designing our project.

Sustainability: Sustainability is obviously a large problem for a device that will be repeatedly hit with very large amounts of force. To protect the head device we have the board sealed in a special memory foam casing in a headband the user will wear. The packaging also has to be water resistant and resilient to heat. Keeping Sports Telemetry Device working properly for extended periods of time has been a very difficult task and required proper planning and design.

Manufacturability: Both the basestation and behind the head boards have only IC's and connectors to solder on. There are no heat sinks or large components needed to be placed which makes manufacturability fairly straightforward. The boards themselves are no bigger than a few inches in area and would keep resources needed to produce the boards low. The housing for the head board currently is a head band, but this is only a prototype. The final product would be created out of a special carbon fiber material with rubber legs that would fit similarly to headphones, but much slimmer.

(f) Description of the multidisciplinary nature of the project.

Sports Telemetry Device required knowledge of not only electrical systems but mechanical physics and neurobiology. We had to understand the mechanical forces that cause concussions and other brain trauma. Without proper knowledge of the physical response of a skull to blunt trauma (at various magnitudes and angles) the sensors could not be properly oriented and the data we obtain would not be accurate. We discussed the location of the sensors in depth with the Purdue Neurotrauma Group to gain better perspective of the neuroscience behind a concussion.

(g) Description of project deliverables and their final status.

Our project comes in two packages. One is a the BTE monitoring unit that will sit in a headband. This unit has a microprocessor, multiple sensors, a NAND flash chip and a Zigbee IC. The board is fully capable of gathering the analog data from the sensors, writing it into NAND flash, reading it from NAND flash and outputting the data via a micro USB connection. The board is also capable of recharging its lithium-polymer battery when USB is plugged in. This satisfies 4/5 PSSCs. The base station is fully constructed with a plastic housing box, but the microprocessor is not functional and can only recharge the battery when plugged. However the all functions of the base station are redundant and are found on the monitoring unit as well. The last PSSC was to establish a mesh network which was not completed. Inadequate Zigbit IC documentation really hindered any progress to establish a network.